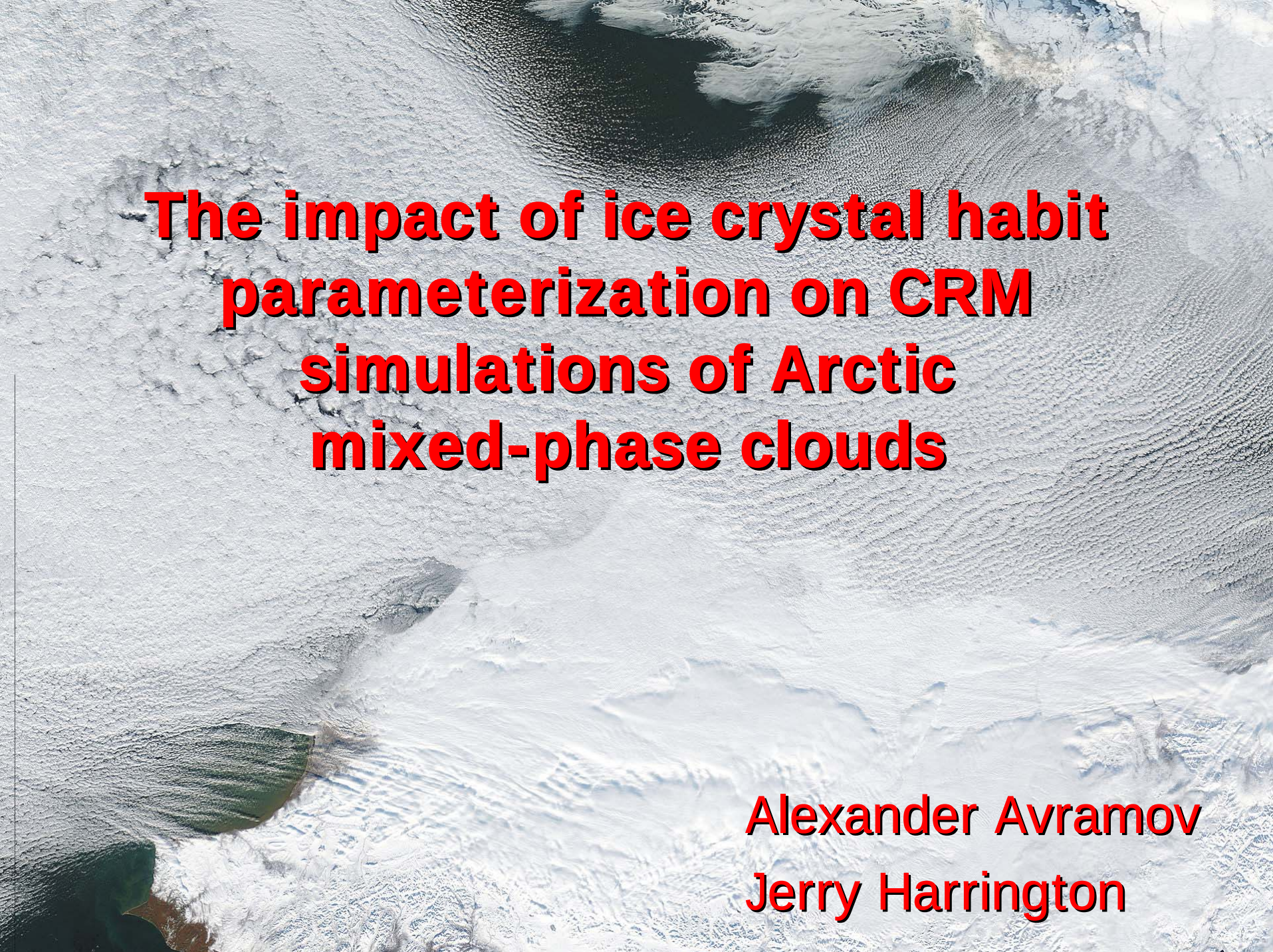


The impact of ice crystal habit parameterization on CRM simulations of Arctic mixed-phase clouds

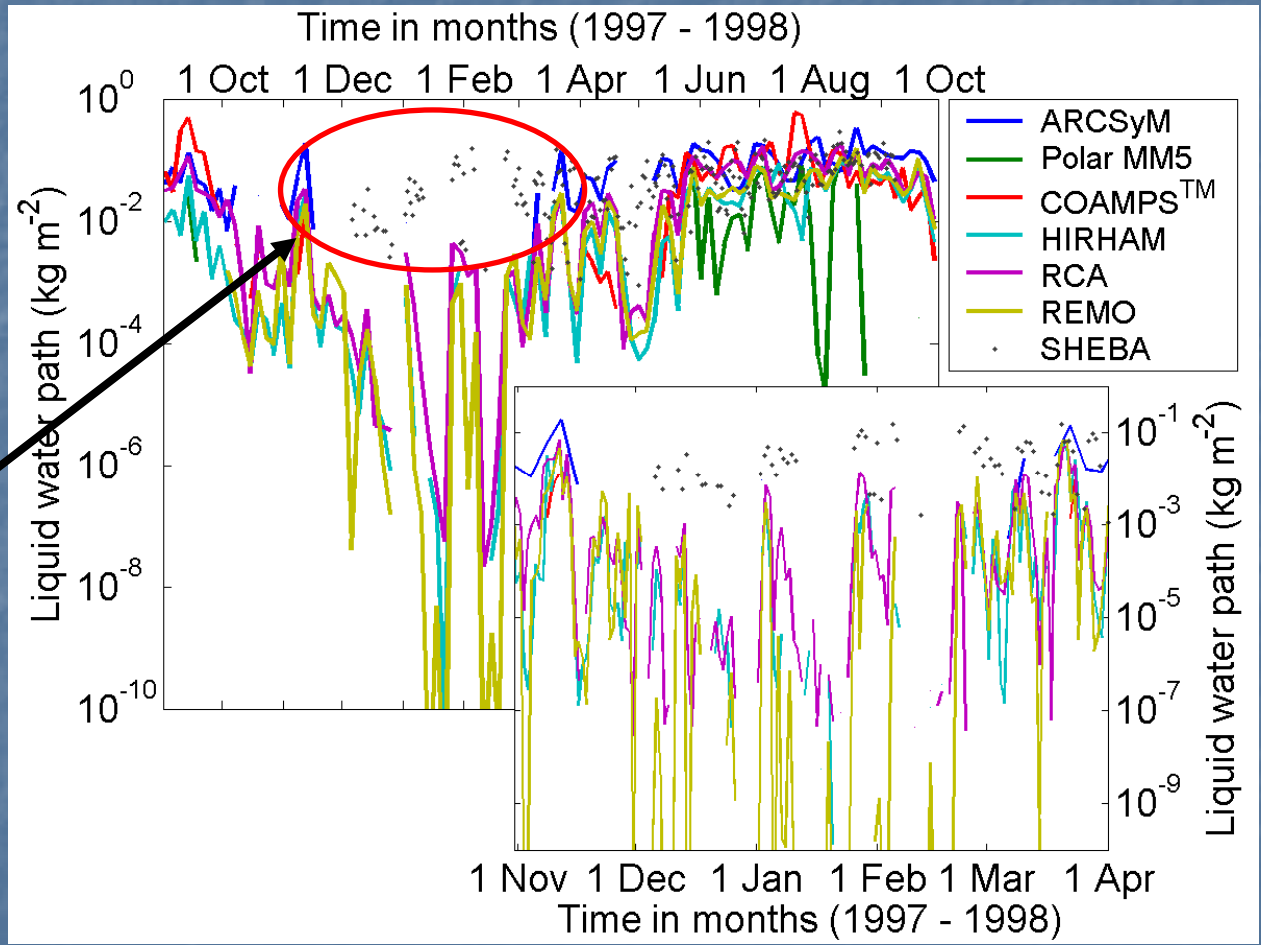
Alexander Avramov

Jerry Harrington

Regional climate simulations

- ARCMIP study
  - SHEBA case
  - Six regional models
  - 1 year long simulation

Liquid water significantly under-estimated during the winter in all models

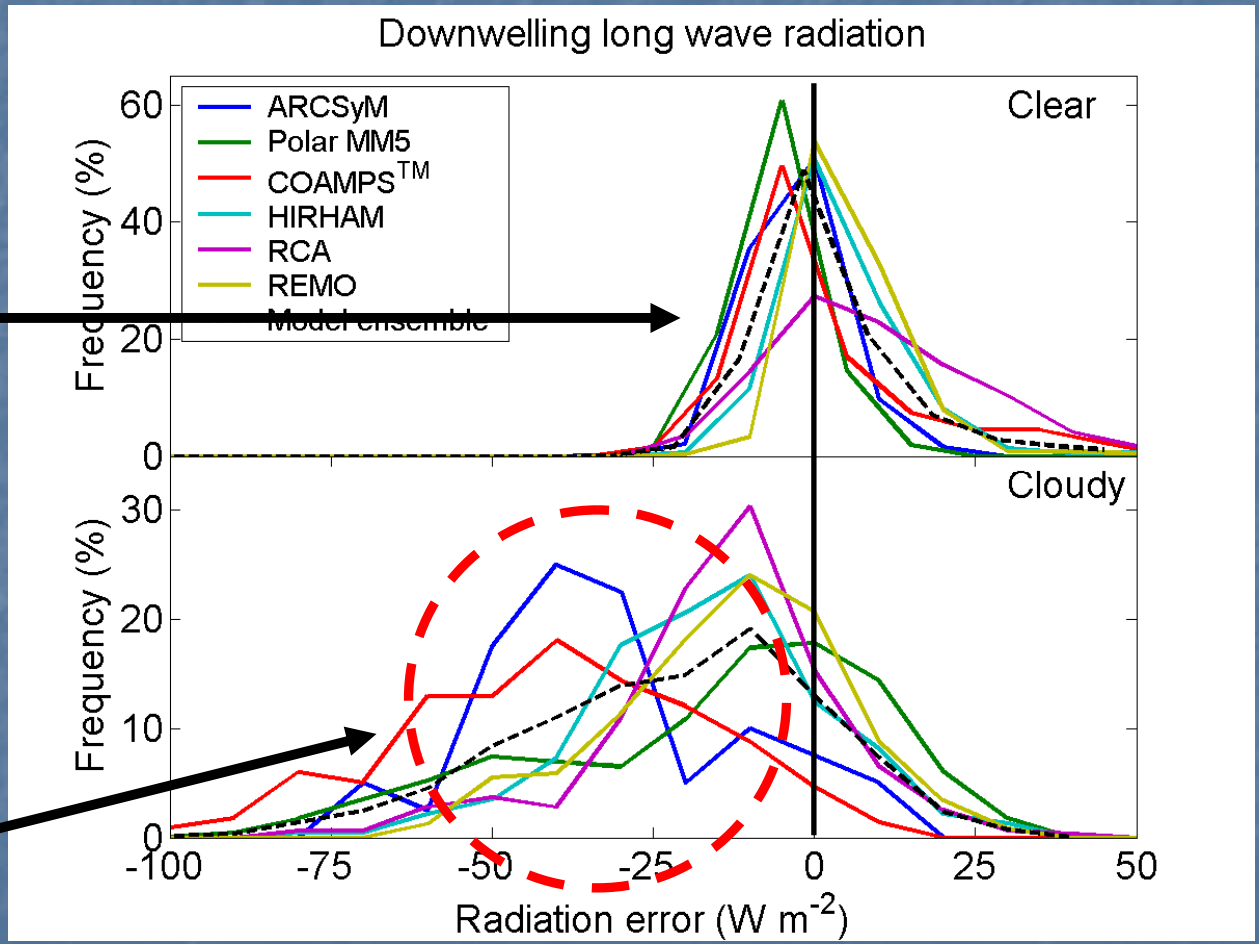


Prenni et al. (2007)

Radiative impact

Small errors centered around 0

Negative bias during cloudy conditions

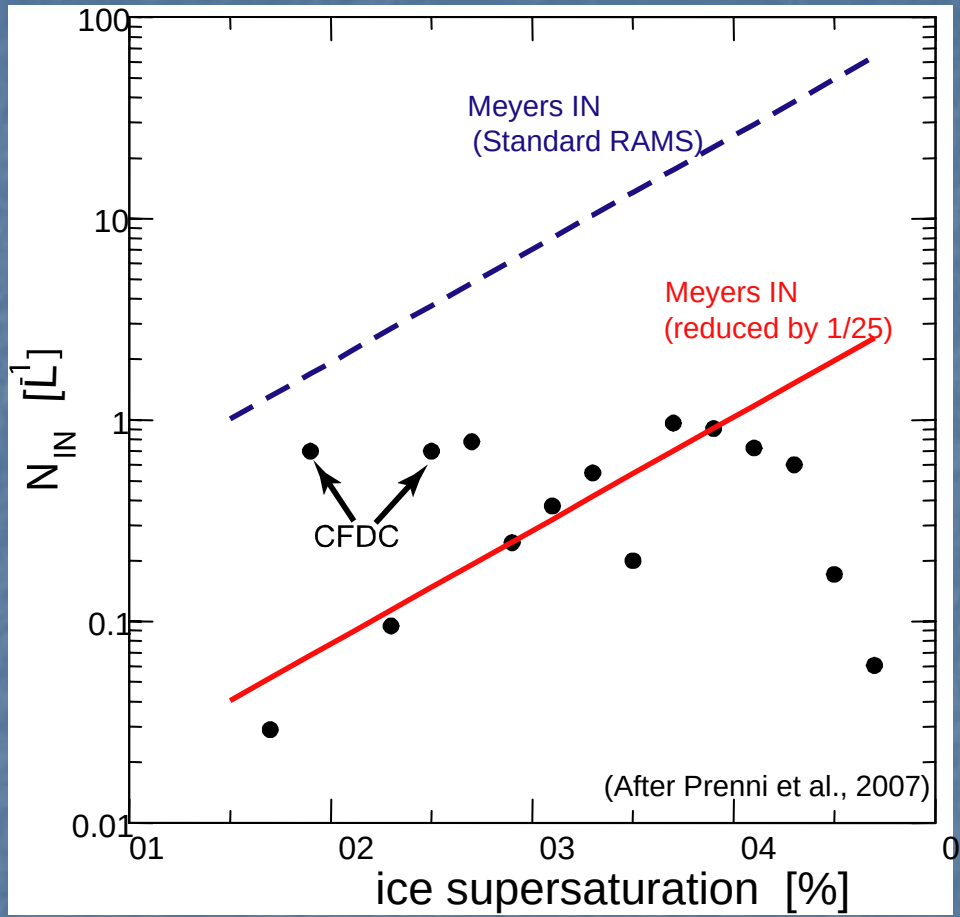


Too little liquid leeds to too much surface infrared loss => predicting liquid important !

Prenni et al. (2007)

Ice Nuclei Parameterization

- Aircraft measurement of IN from Colorado State's CFDC (Prenni et al., 2007)
- **Measurements** => very low concentrations of IN throughout the experiment.
- ***Deposition/condensation*** freezing parameterization (Meyers et al, 1992) => new fit from obs data

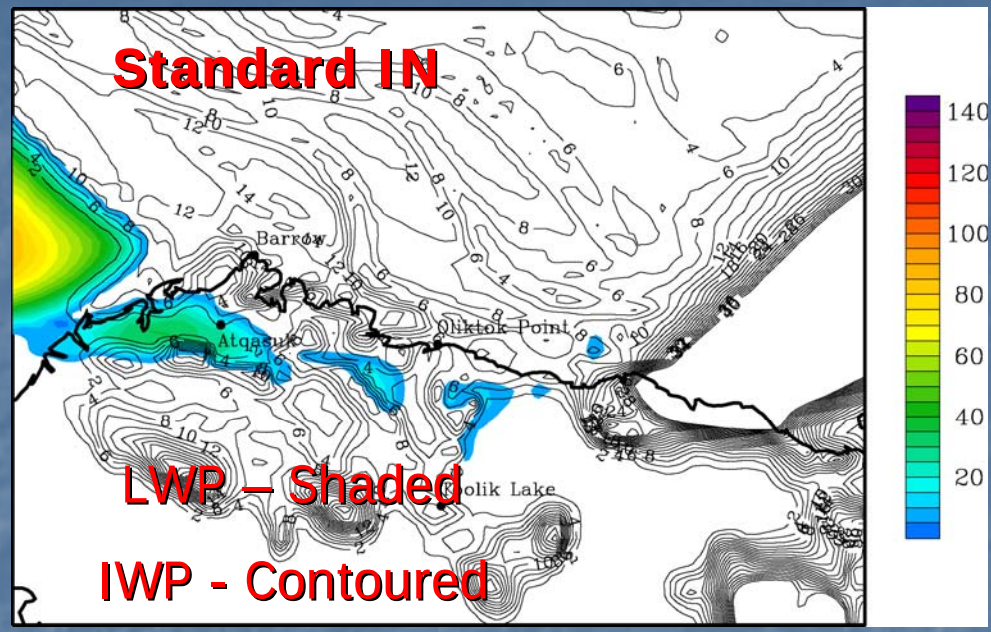


- Because concentrations not well known => Sensitivities to these quantities.

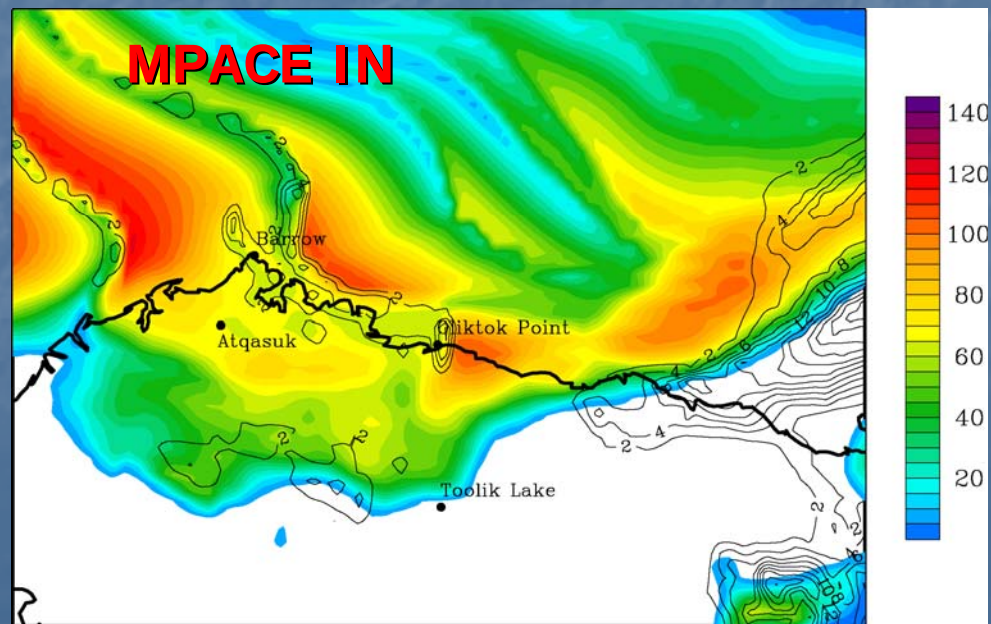
Mesoscale simulation results

Standard IN => cannot maintain liquid

- Crystals remain small, in cloud residence time rises, Bergeron process rapid.

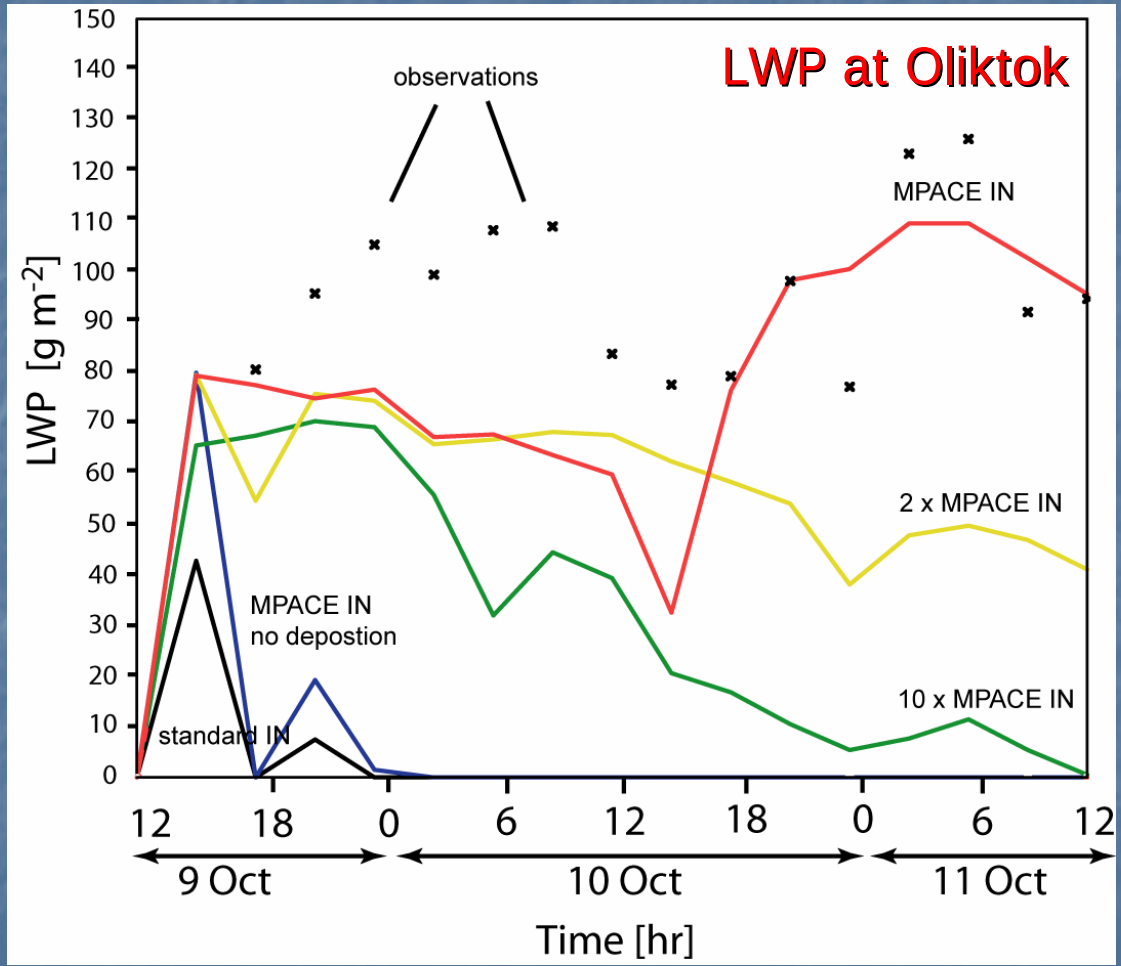


- MPACE IN => supercooled liquid clouds throughout two days
  - Continual light snow precipitation from liquid layers



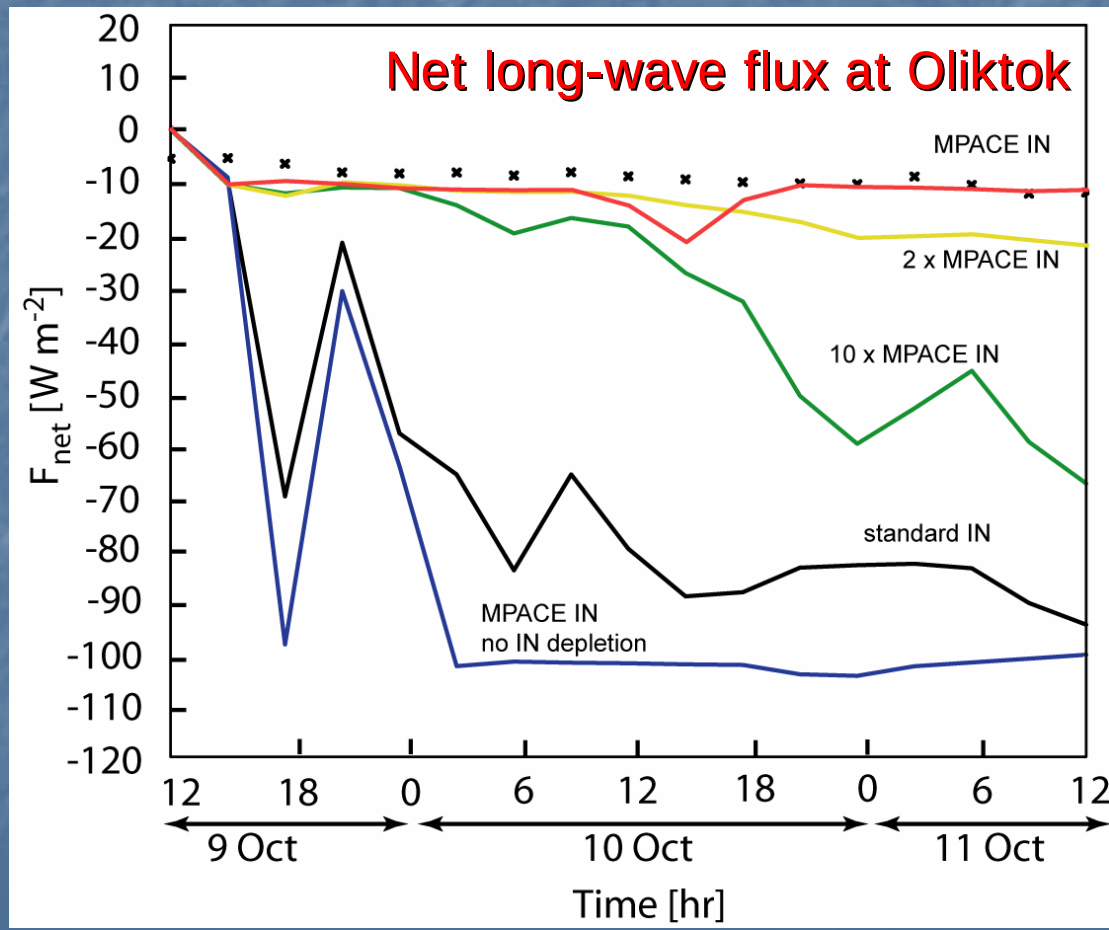
Mesoscale simulation results

- Timeseries of LWP at Oliktok
  - Comparison best with MPACE IN
  - Doubling IN => reduces LWP by ~ half
  - 10x IN => Cloud is dominated by ice



Radiative influences

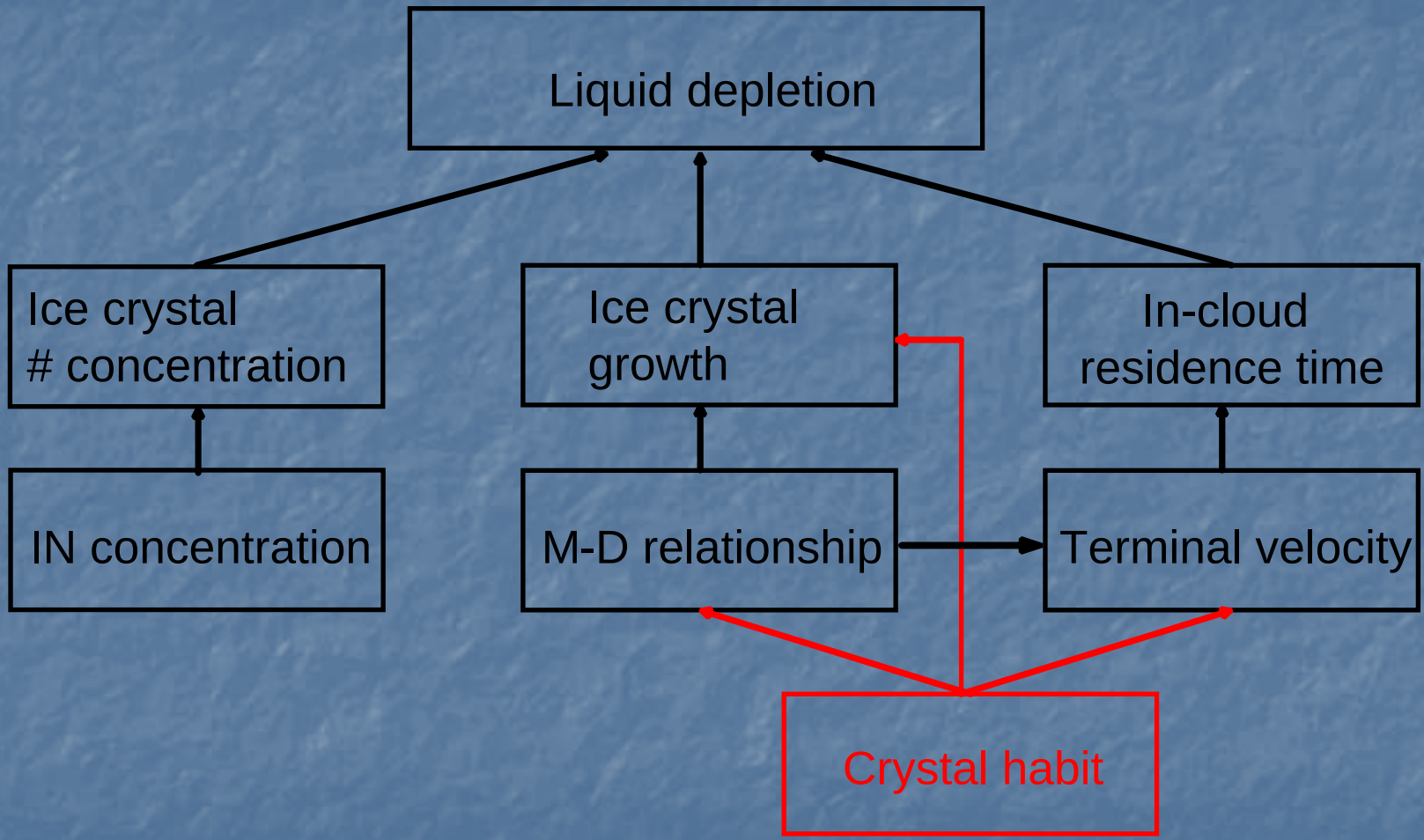
- Comparison best with MPACE IN
- gradually decreasing with IN increase
- errors up to 90 W/m^2
- similar to ARCMIP models



- Simulated clouds are highly sensitive to IN concentrations.

- Poor Arctic aerosol (IN) parameterizations may lead to poor liquid predictions and large radiative errors.

- **But, other studies (Fridlind et al., 2007; Morrison et al., 2008) do not show the strong sensitivity to IN concentrations that our simulations show. Why?**


Liquid depletion
Ice crystal
concentration
Ice crystal
growth
In-cloud
residence time
IN concentration
M-D relationship
Terminal velocity
Crystal habit

How does the habit impact simulations ?

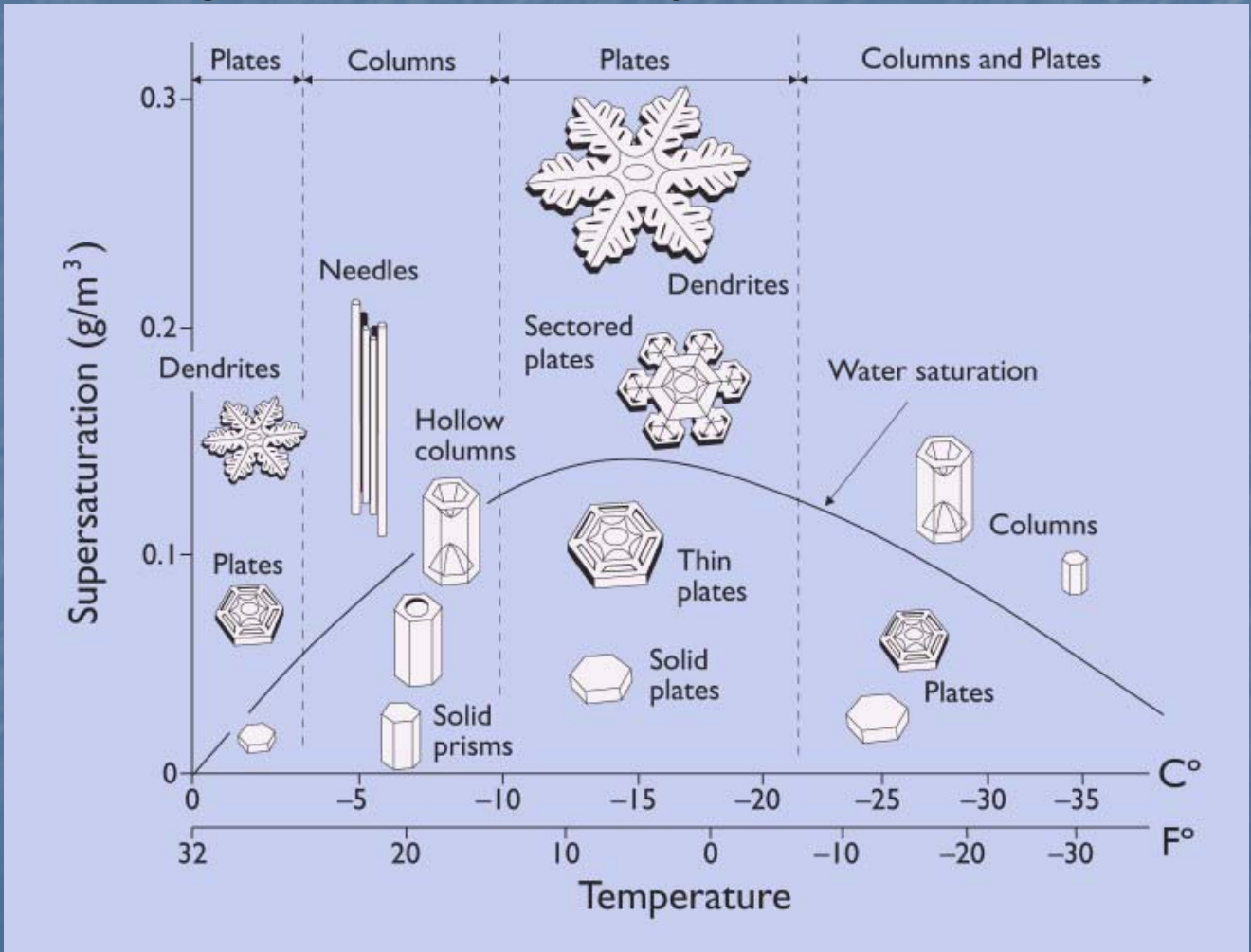
- sedimentation velocity – parameterized as a function of crystal size; different for each habit
- capacitance term in the mass growth equation:

$$\frac{dm}{dt} = 2\pi DS \nabla \rho_v$$

- mass-dimensional relation – needed in 2-moment schemes, also different for each habit

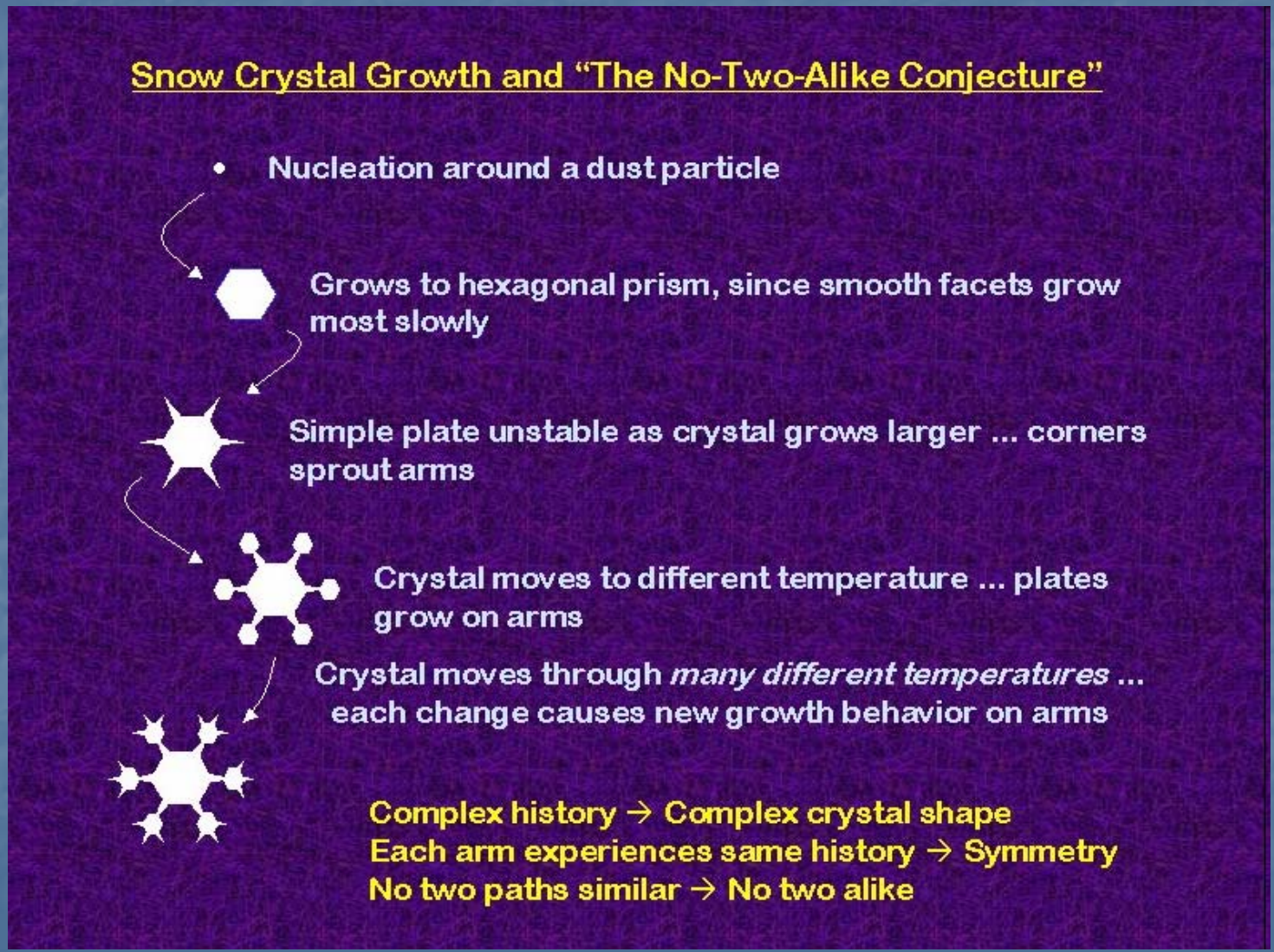
Ice crystal habits

Varying conditions of temperature and vapor pressure lead to growth of different crystalline forms



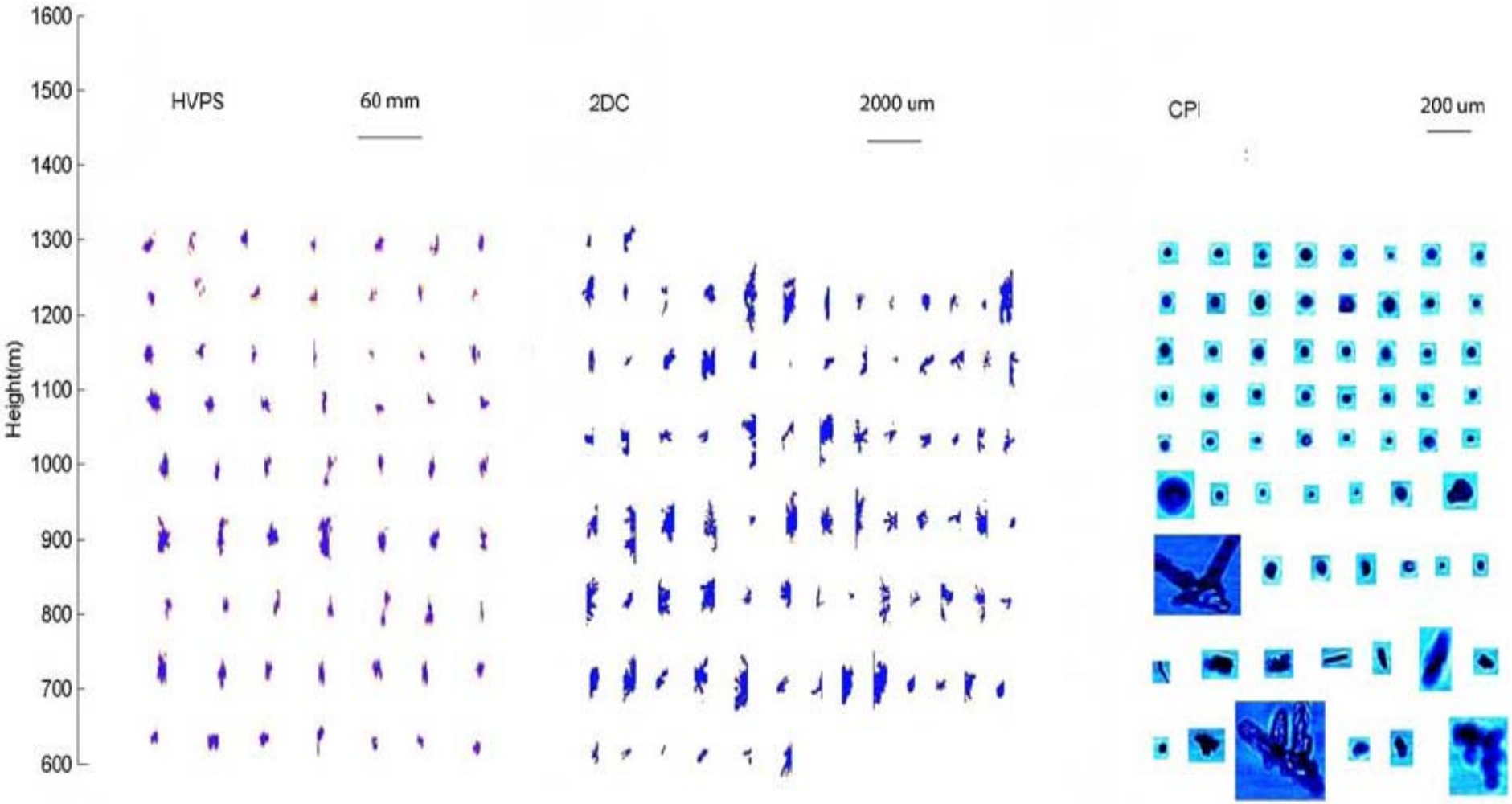
Librecht (2005)

Habit evolution



www.Snowcrystals.com

Real life crystals

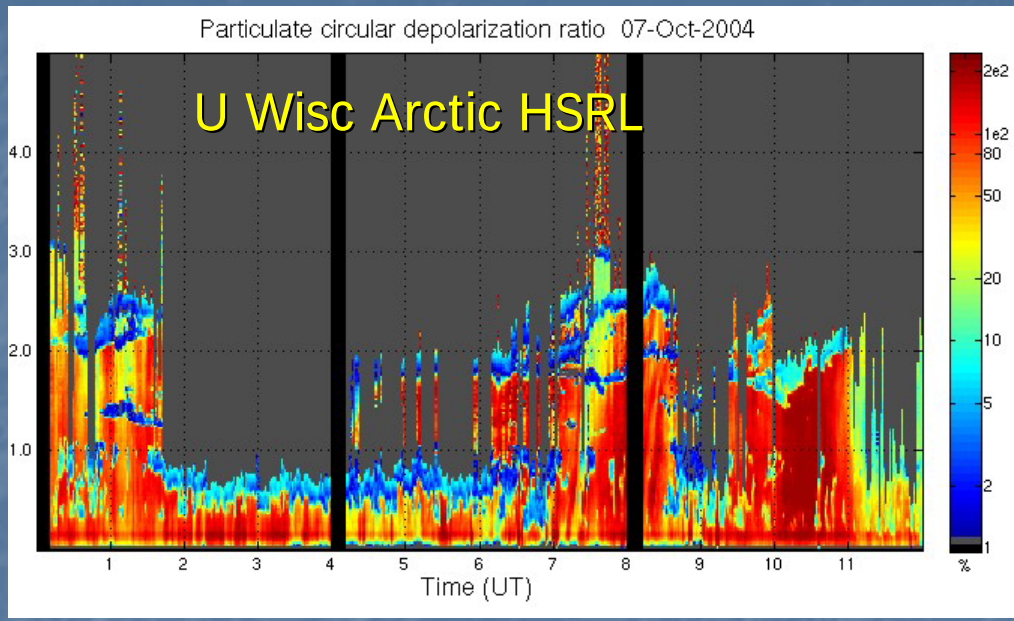


McFarquhar et al (2007)

M-PACE Model Inter-comparison Study

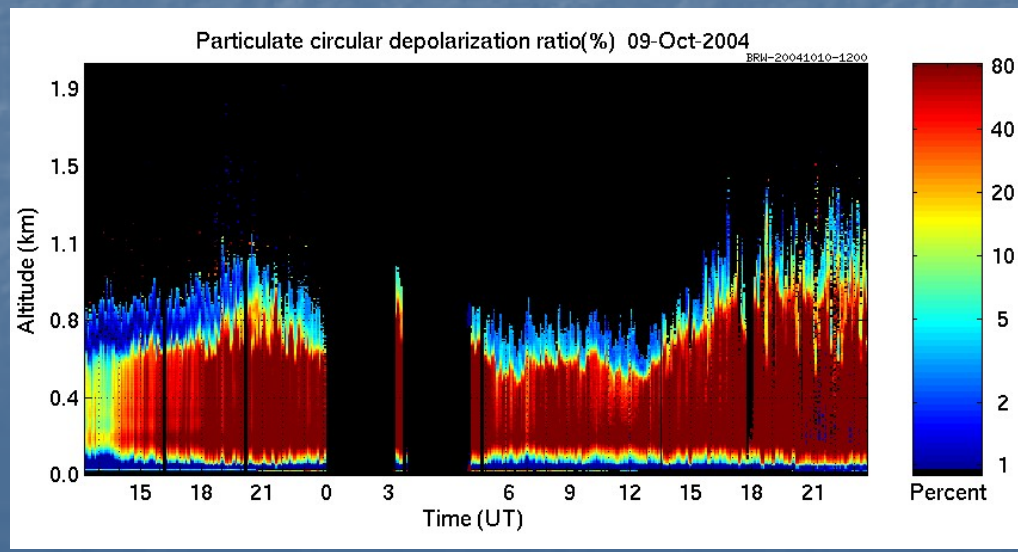
- **Case A:** ***Oct 5 – 8, 2004***

  several liquid layers with ice crystals settling between them



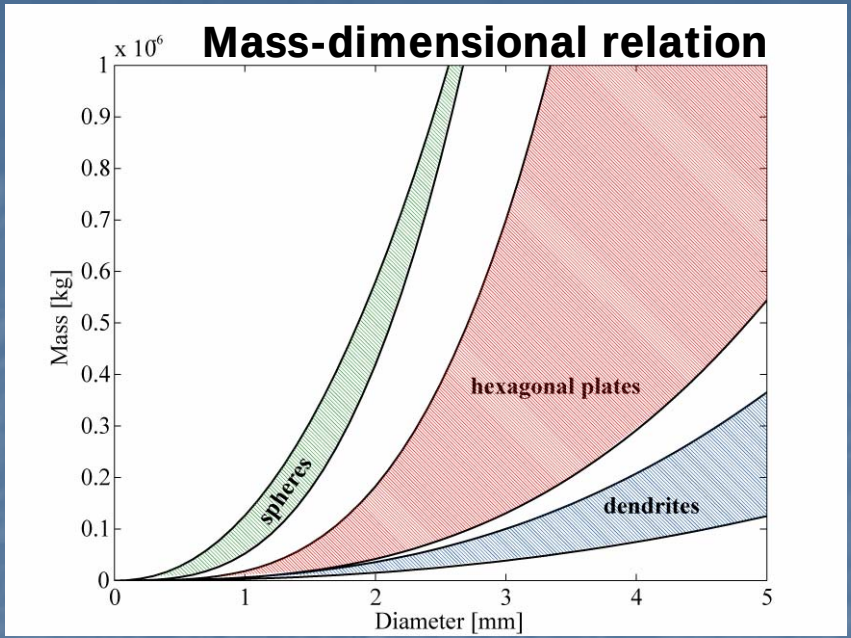
- **Case B:** ***Oct 9– 11, 2004***

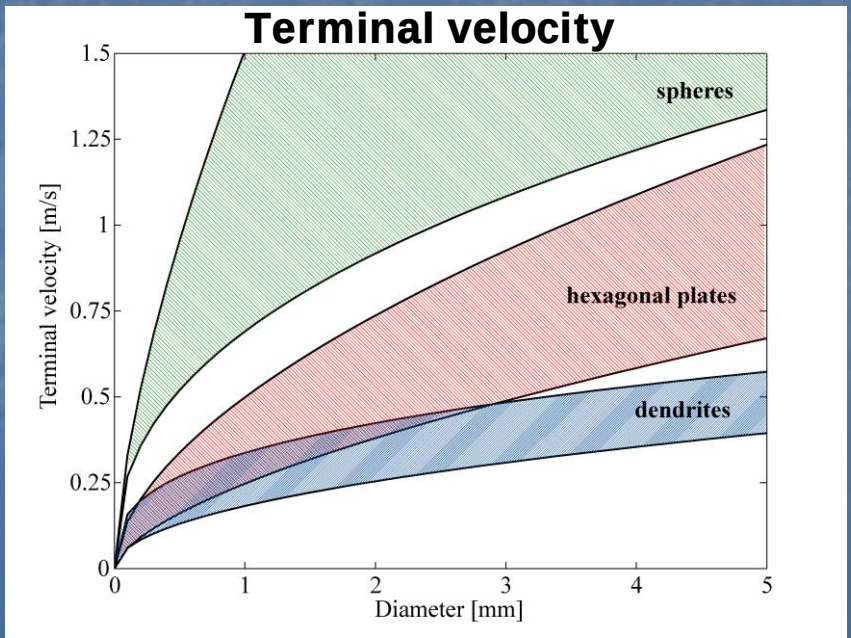
  single layer mixed-phase cloud



Simulation design

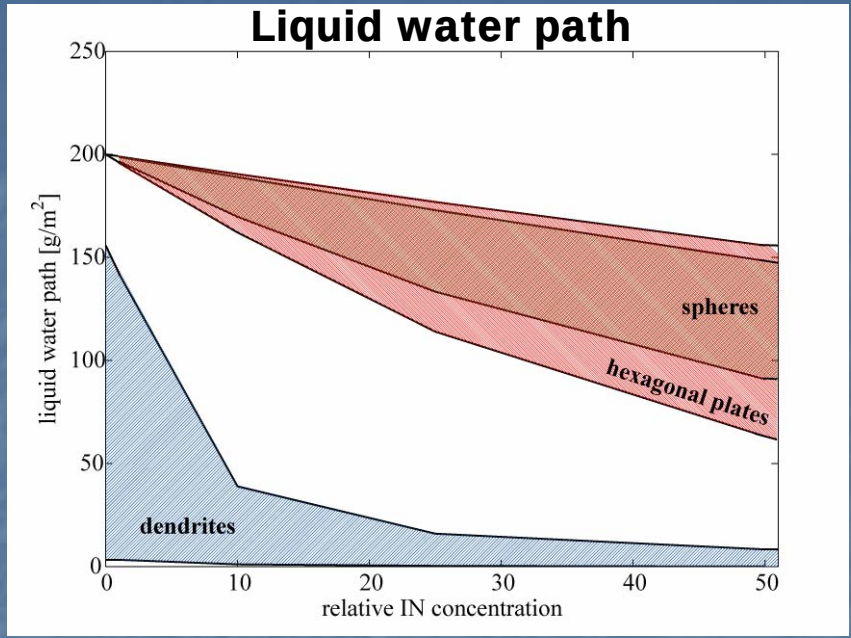
- Model: RAMS@CSU in CRM configuration
- 3 basic habits selected: spheres, hexagonal plates and dendrites
- the limits of M-D and terminal velocity relations were identified for each of the habits
- a series of simulations for each combinations of these limits for each habit

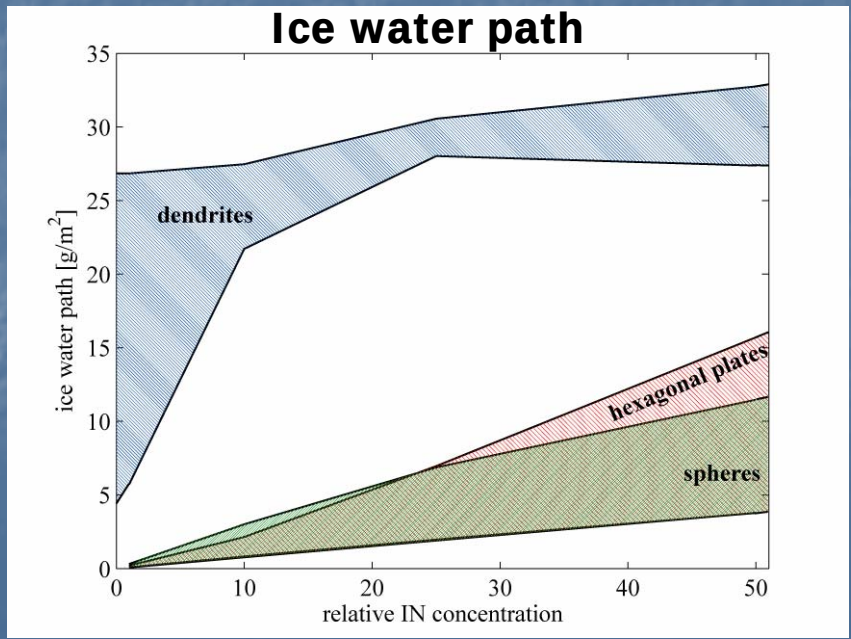




LWP and IWP ranges single layer case

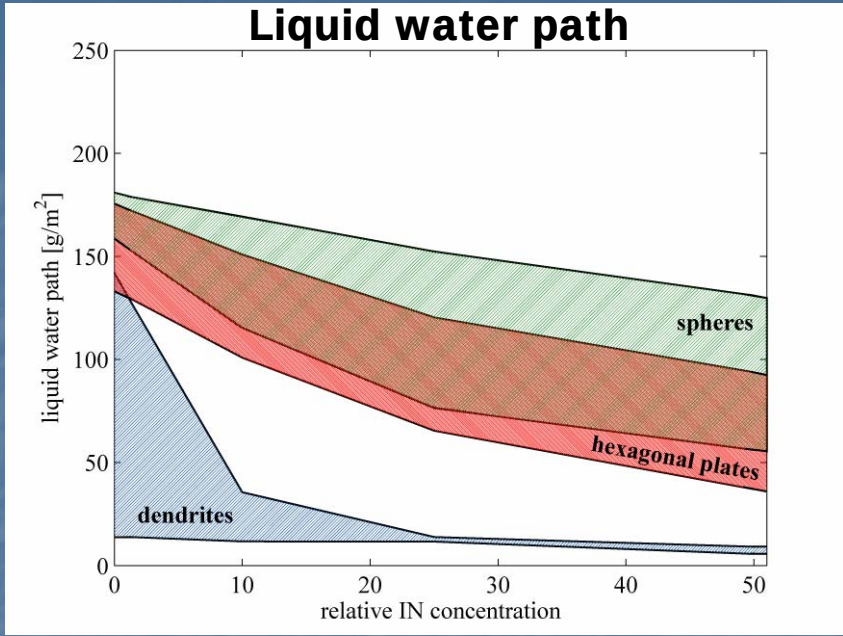
- Spheres and hexagonal plates: largest liquid and lowest ice water path. Low to moderate sensitivity to IN concentrations.
- Dendrites: greater ice and lower liquid water path. Extremely high sensitivity to IN concentrations.

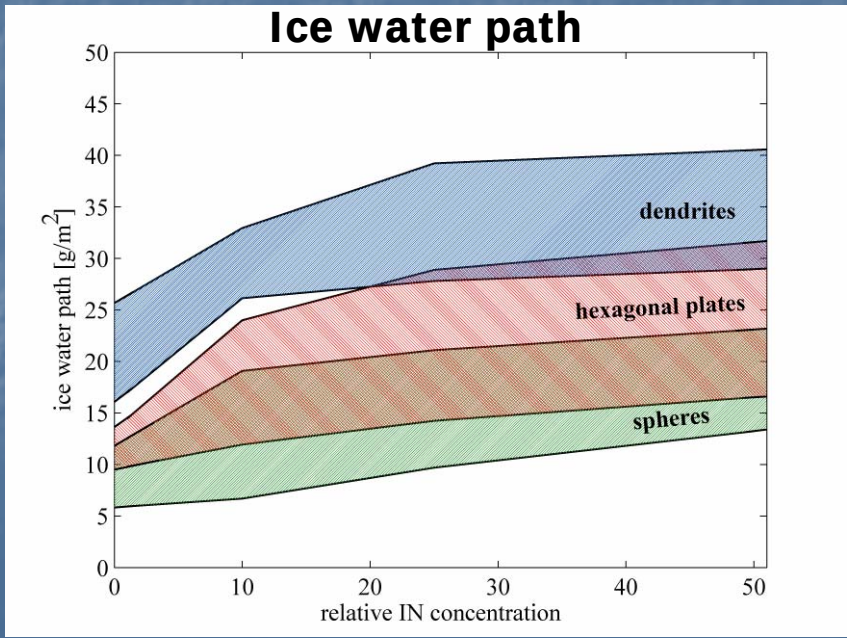




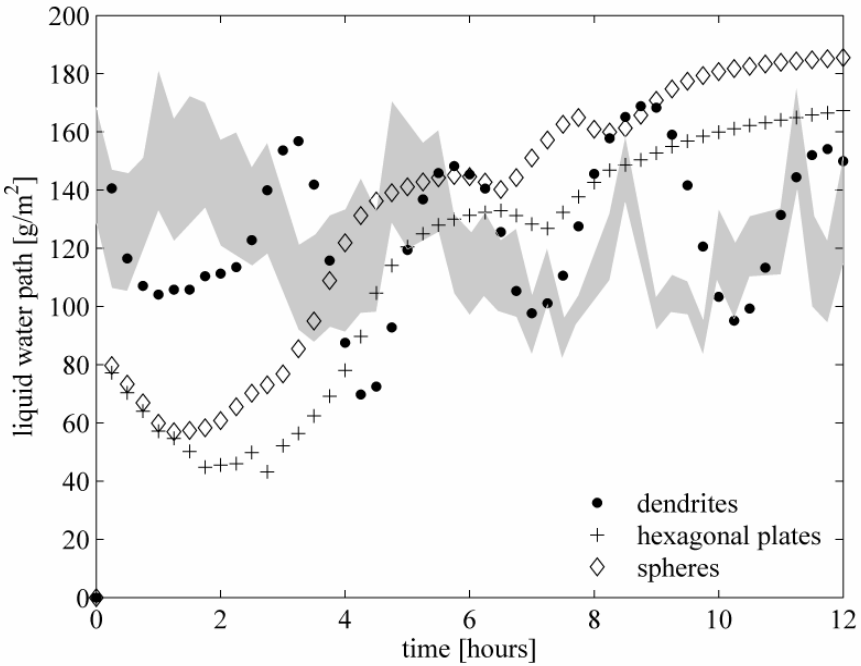
LWP and IWP ranges multi-layered case

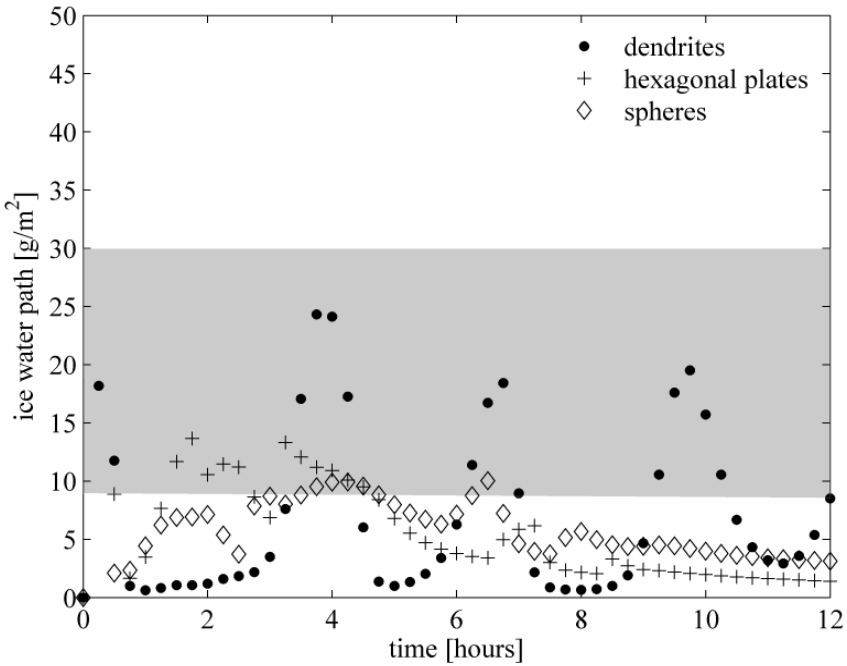
- Similar results for multi-layered case.
- Spheres and hexagonal plates: largest liquid and lowest ice water path. Low to moderate sensitivity to IN concentrations.
- Dendrites: greater ice and lower liquid water path. Extremely high sensitivity to IN concentrations.



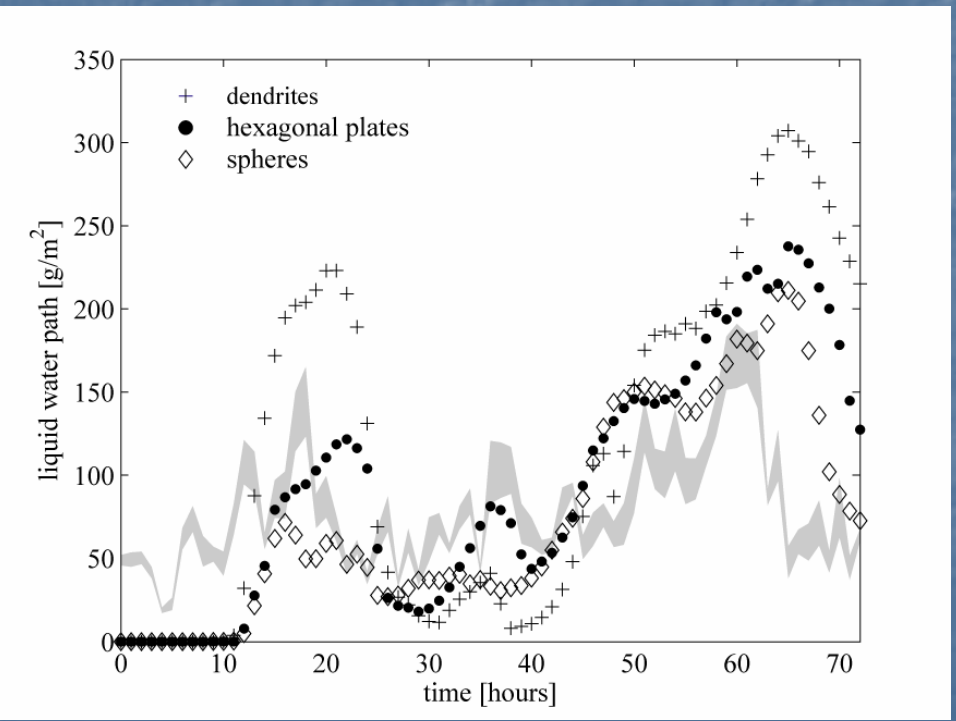


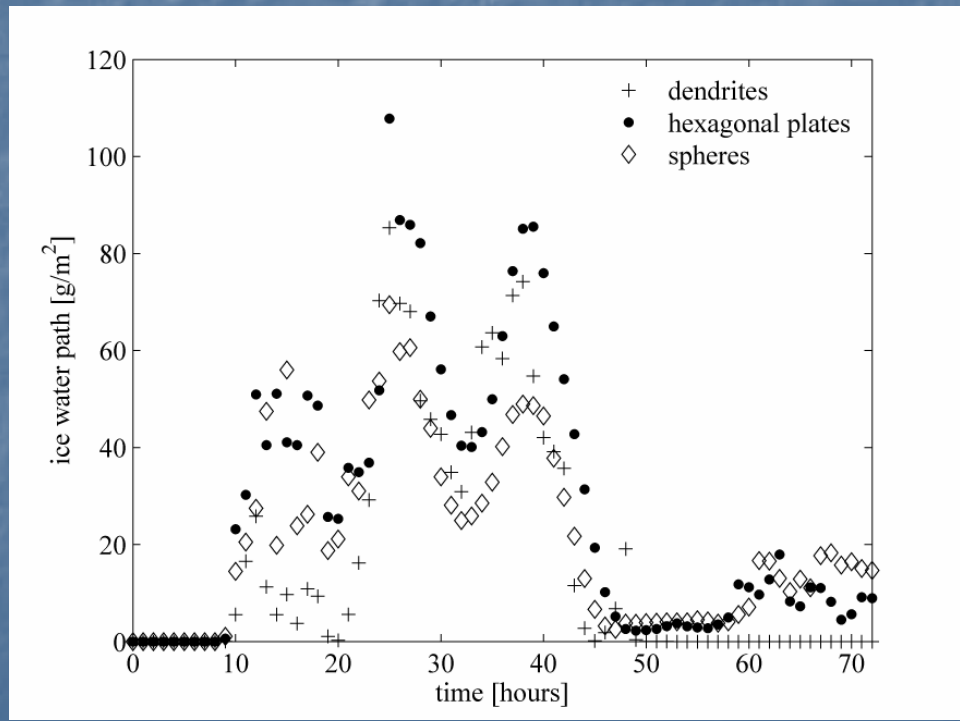
Liquid and ice water path single layer case



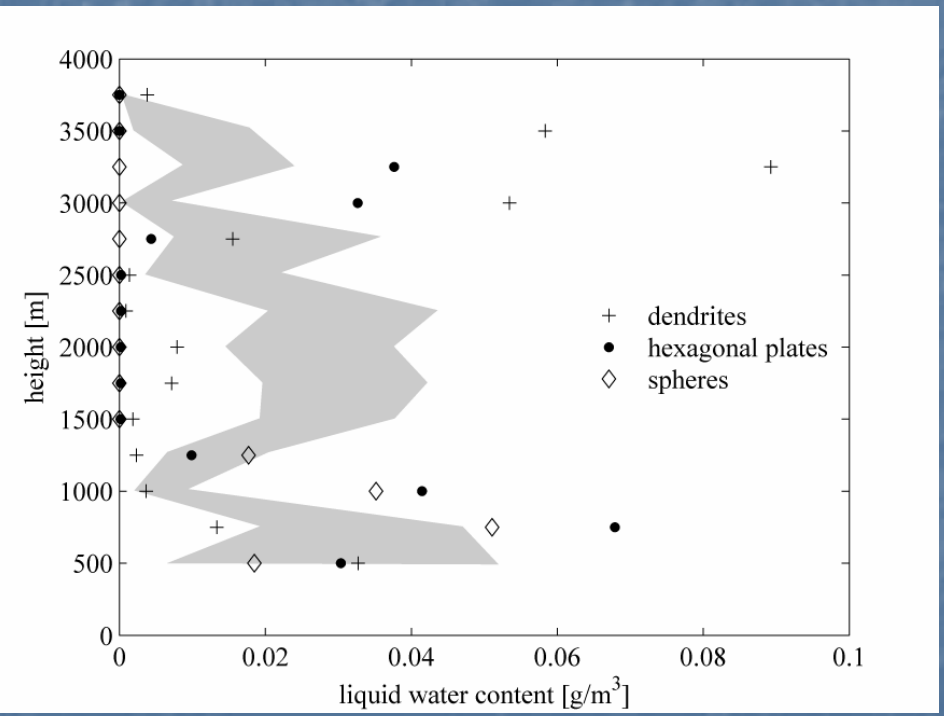


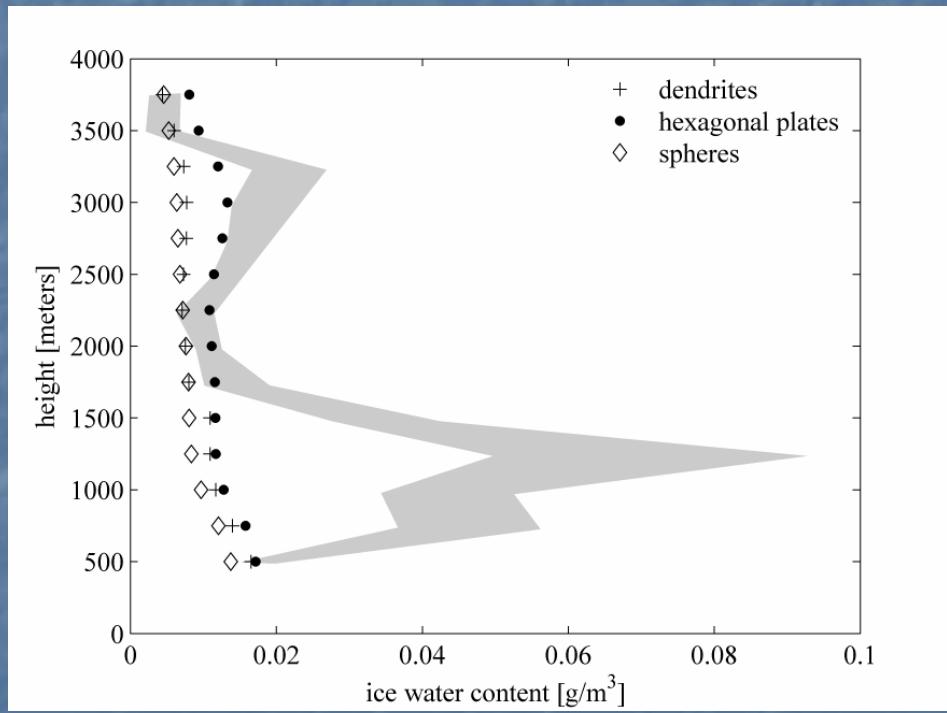
Liquid and ice water path multi-layered case



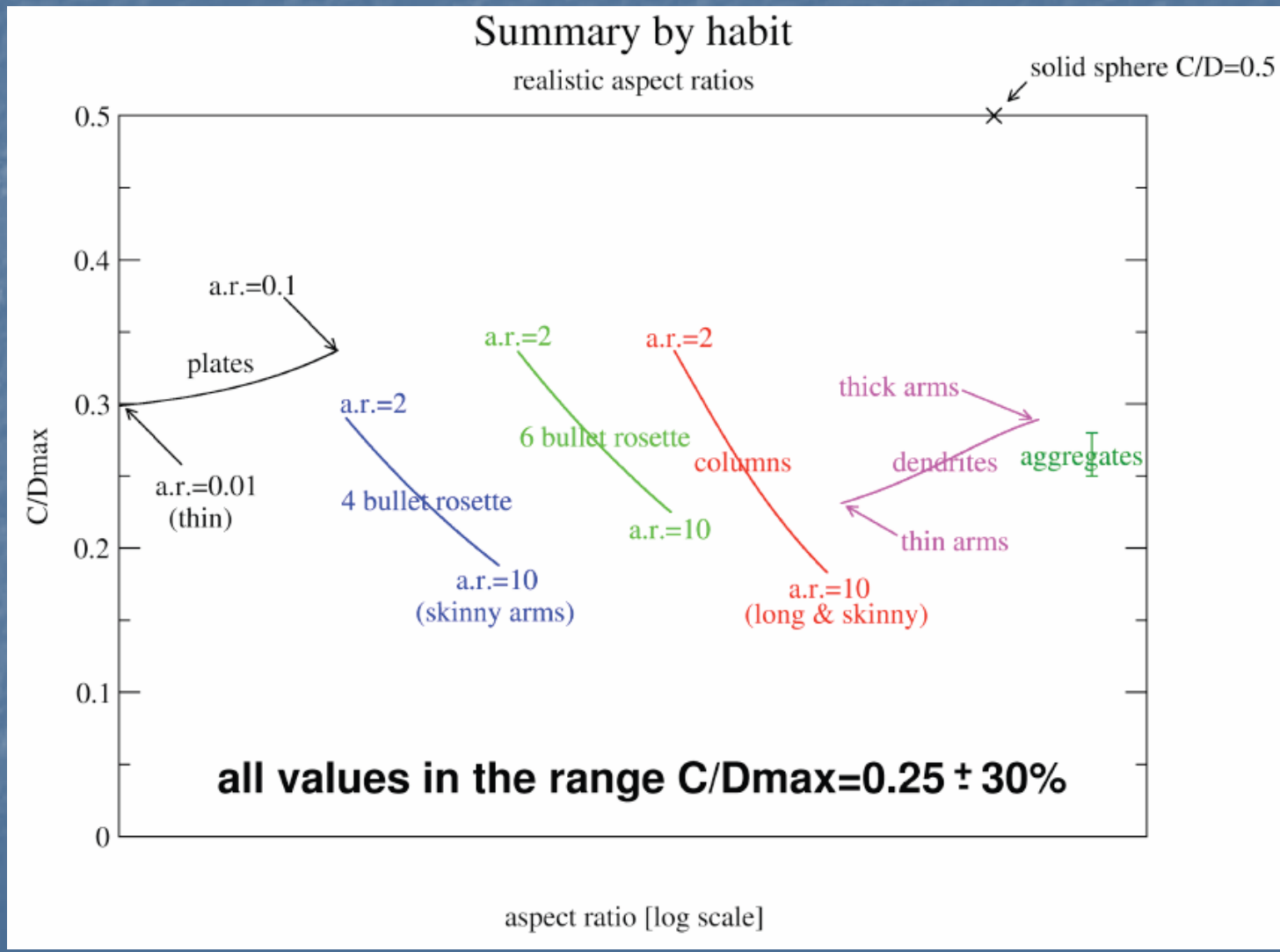


Liquid and ice water content multi-layered case





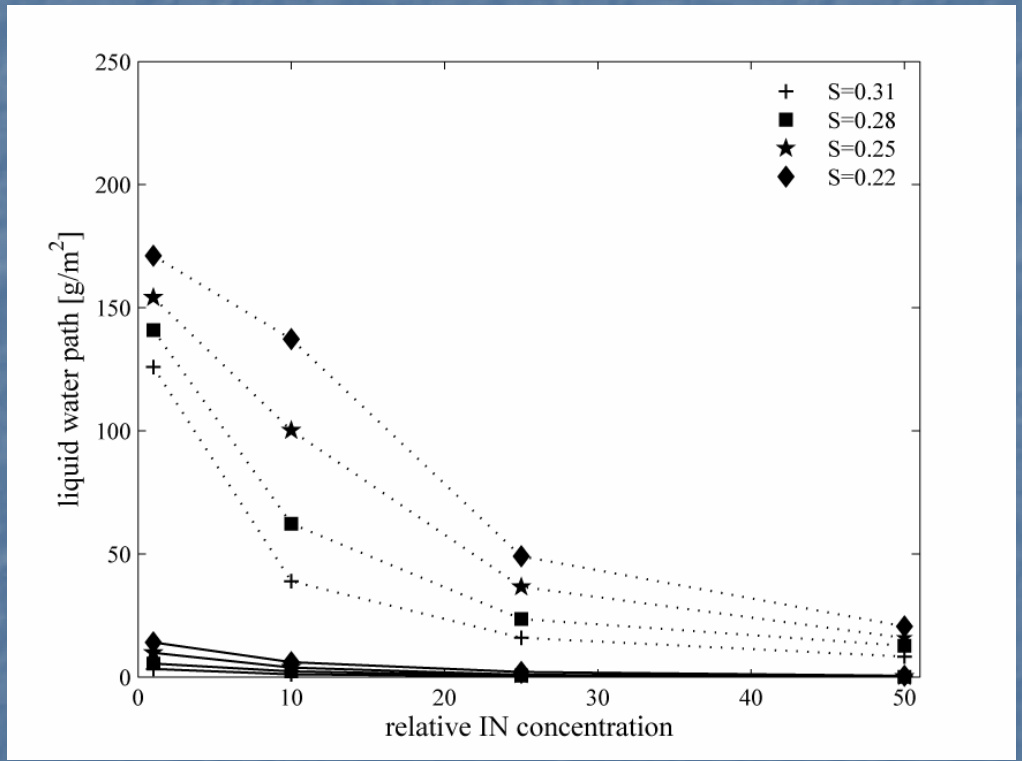
Shape parameter



Westbrook et al. (2007)

Shape parameter influence

- Crystal capacitance is parameterized as a function of crystal' size and "shape parameter".
- For spheres and hexagonal plates the shape parameter is known.
- Dendrites: varies depending on the arms aspect ratio.



Conclusions

- Simulated mixed-phase clouds ARE sensitive to IN concentration.
- The ice/liquid water partitioning in simulated clouds and the IN sensitivity, as well, depend strongly on the assumed crystal habit and associated mass-dimensional and terminal fall velocity relationships.
- Almost ANY range of LWP and/or IWP can be produced by careful choice of crystal habit and associated with it mass and terminal fall speed relations.
- The ice crystal habit – too powerful “tuning knob”

Conclusions

- Fixed habit approach appears to be inadequate as applied in mixed-phase cloud simulations
- Simulating changes in crystal habit (similar to “adaptive growth” concept of Chen and Lamb, 1994) is of vital importance for simulations of mixed-phase clouds
- Research models prediciting habit changes: Hashino and Tripoli (2007), Morrison and Grabowski